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# The impact of a large-scale natural disaster on patients with chronic obstructive pulmonary disease: The aftermath of the 2011 Great East Japan Earthquake

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ABSTRACT

*Background:* A large-scale natural disaster may exacerbate chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD). The aftermath of a natural disaster can include poor access to medication, medical equipment, and medical supplies. Little is known about the impact on patients with COPD.

*Methods:* A retrospective cohort study was conducted at a regional medical center in Ishinomaki, the area affected most severely by the Great East Japan Earthquake in 2011. The study was performed 6 months after the disaster. The characteristics, clinical courses, and outcomes of COPD patients hospitalized after emergency visits during the study period were investigated and compared.

*Results:* One hundred patients (112 episodes) were identified. Within a few days after the disaster, patients undergoing oxygen therapy at home came to the hospital to receive oxygen. In the subacute phase (from the third to the fifth week), the number of hospitalizations due to COPD exacerbations was significantly increased compared to the numbers observed before the earthquake ($p<0.05$). On admission, COPD patients reported significantly reduced participation in the activities of daily living (ADLs) after as compared to before the disaster. The incidence of cases of exacerbated COPD normalized 6 weeks after the earthquake.

*Conclusions:* The large-scale natural disaster that hit Japan in 2011 had a serious negative impact on the clinical outcomes of COPD patients in the disaster-affected area.



Abbreviations: ADL, activities of daily living; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; NPPV, noninvasive positive pressure ventilation

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## 1. Introduction

Large-scale natural disasters, such as earthquakes or tsunamis, destroy buildings, vital infrastructure, communication technology, and transportation facilities, often resulting in many deaths and traumatic injuries. Medical resources and public health services are also often severely impaired. These disasters may exacerbate chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD). In the aftermath of the disaster, COPD patients often endure limited access to medication, medical equipment, and/or medical supplies. However, no systematic investigation has examined the impact of natural disasters on patients with COPD.

An earthquake of magnitude 9.0 occurred in Japan on March 11, 2011, most severely affecting the Tohoku region on the northeast coast of the country. A devastating tsunami followed the earthquake and caused widespread damage on Japan's eastern coast. Approximately 20,000 people were killed or went missing, and over 380,000 houses were destroyed [1]. In the aftermath of this catastrophe, we dealt with respiratory emergencies at a regional medical center set up in Ishinomaki to deal with the disaster's aftermath. We conducted a retrospective cohort study to evaluate the impact of the disaster on clinical outcomes among COPD patients.

## 2. Material and methods

### 2.1. Study design

We conducted a retrospective cohort study at the Japanese Red Cross Ishinomaki Hospital in Ishinomaki, Japan. The institution is a 402-bed tertiary hospital, which provides medical services to over 220,000 people in Ishinomaki and the surrounding cities. Ishinomaki is a port town located in the coastal area of Tohoku region and was one of the most affected cities by this disaster. The Japanese Red Cross Ishinomaki Hospital was designated as the region's primary medical center after this disaster. Although other medical facilities in Ishinomaki were either destroyed or damaged by the tsunami, the Japanese Red Cross Ishinomaki Hospital continued to operate at full capacity [2]. Remarkably, the electronic medical record system remained functional as well. Clinical laboratory and radiology services were also available. In the first 7 days after the disaster, we were able to treat 3938 emergency patients at the hospital.

This study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee at the Japanese Red Cross Ishinomaki Hospital (December 5, 2011).

### 2.2. Inclusion and exclusion criteria

We reviewed the medical records of patients who made an emergency visit and required a hospital stay during the period from March 11 to September 10, 2011, and identified patients diagnosed with COPD in accordance with the GOLD criteria [3]. Each patient presenting with aggravated symptoms underwent a comprehensive assessment that included a physical examination, pulse oximetry, chest radiography, and electrocardiography. COPD exacerbation was defined as a sudden worsening of symptoms such as increased breathlessness, coughing, or sputum production, thereby requiring additional treatments [3]. Patients with symptoms exacerbated by congestive heart failure were excluded from the study. Patients with advanced cancer whose disease stabilization could not be achieved were also excluded. Patients who had received oxygen therapy at home and required emergency visits were included. We reviewed the medical records of COPD patients hospitalized due to exacerbations in the corresponding periods of 2009 and 2010 as controls.

### 2.3. Data collection

Sociodemographic characteristics, smoking status, and maintenance treatments at baseline were recorded for each patient. The presence of comorbidities, including congestive heart failure, ischemic heart disease, chronic liver disease, chronic renal disease, diabetes, and cancer was also assessed [4]. Pulmonary function tests were performed under stable conditions within a year before the emergency visit or after recovery from the symptoms induced by the disaster. The severity of COPD was defined in accordance with the GOLD criteria [3]. The ADLs of patients upon admission and before the earthquake were evaluated by interviewing patients or their caregivers. ADLs were classified as "good" if they could live without support, "fair" if they could not leave their residence without support or "poor" if they spent days in bed or in a chair and had lost the ability to move independently. Data relating to symptom exacerbation including the final diagnosis, treatment, and length of hospital stay were collected as well.

Patients were followed up at the outpatient clinic for over 3 months after discharge. If a patient was referred to another hospital, we contacted the institution and inquired about the patient's clinical course.

### 2.4. Statistical analyses

Individual comparisons were performed using the Wilcoxon signed-rank test. The non-parametric Wilcoxon rank sum test was used for the comparisons of categorical variables. Simple regression analysis was performed using the least squares method. P values less than 0.05 were considered significant. All analyses were performed using JMP software (SAS Institute Inc., NC).

## 3. Results

We identified 100 COPD patients (112 episodes) who presented at the emergency department and required hospitalization within 6 months after the disaster. The characteristics of the patients are shown in Table 1. The diagnosis and clinical course of each patient is presented in Tables 2 and 3. The details are provided below.

**Table 1 – Patient characteristics.**

| | |
|---|---|
| Age (years) | 78 (10) |
| Sex, male/female | 89/11 |
| *Residence* | |
| Home | 84 |
| Community evacuation center | 12 |
| Nursing home | 3 |
| Other hospital | 1 |
| Smoking history, pack-year[a] | 55 (40) |
| *Pulmonary function test*[b] | |
| FEV1, L | 0.93 (0.75) |
| %FEV1 (%) | 45.1 (29.3) |
| FEV1/FVC | 0.41 (0.18) |
| *GOLD stage*[b] | |
| Stage I/II/III/IV | 6/29/20/29 |
| *Comorbidities* | |
| Congestive heart failure | 14 |
| Ischemic heart disease | 3 |
| Chronic liver disease | 4 |
| Chronic renal disease | 1 |
| Diabetes | 7 |
| Cancer | 10 |
| Long-term oxygen therapy | 46 |

Each data-point is presented as a number or median (interquartile range).
FEV1: forced expiratory volume in 1 s, %FEV1: percentage of predicted FEV1.
[a] Smoking history was not available in 11 patients.
[b] Pulmonary function testing was not available for 16 patients.

**Table 2 – Diagnoses and clinical courses of 112 episodes.**

| | |
|---|---|
| *Diagnosis* | |
| Exacerbations of COPD | 68 |
| Oxygen-dependent evacuee | 36[a] |
| Pneumothorax | 8 |
| Pulmonary embolism | 0 |
| *Introduction of ventilator support* | |
| NPPV | 7 |
| IMV | 2 |
| Length of hospital stay (days) | 10 (8) |
| *Prognosis* | |
| In-hospital death | 6 |
| Death within 90 days[b] | 10 |

Each data-point is presented as a number or median (interquartile range).
NPPV: noninvasive positive pressure ventilation, IMV: invasive mechanical ventilation.
[a] One patient who lost his oxygen equipment visited after closure of the temporary evacuation center.
[b] At 90 days, 10 patients were lost to follow-up.

### 3.1. *Patients receiving oxygen therapy*

During the period from March 11 to 17, 35 COPD patients who received long-term oxygen therapy at home (including 3 patients using NPPV) presented at the hospital after loss of a stable oxygen supply due to power failure or equipment damage (Fig. 1). Only 12 of these patients were treated at our hospital, with the remaining patients receiving regular treatment by general practitioners ($n=14$) or at other hospitals ($n=9$). These patients were triaged and then transferred to a temporary evacuation center established inside the hospital [5]. None of them showed exacerbated symptoms upon presentation to the hospital, but 20% (7/35) experienced exacerbations requiring additional treatment during their time at the evacuation center. These patients showed exacerbated symptoms on March 15 ($n=4$), 16 ($n=2$), and 17 ($n=1$). Rapid diagnostic tests were used to confirm that none of the patients had influenza. There was no difference between the exacerbated group and the non-exacerbated group in terms of age or gender. Since we could not obtain the results of pulmonary function tests for patients treated at other hospitals, differences in pulmonary function were not evaluated. Patients who were stable returned home when their local-area electricity was restored or were sent to rearward hospitals if they had lost their houses or means of survival. The median length of hospital stay was 9 days; the evacuation center was closed on March 26.

### 3.2. *Exacerbations of COPD*

During the 6-month study period, 63 patients with exacerbations (68 episodes) presented at the emergency department requiring hospitalization. Five patients were hospitalized twice during the study period. The number of patients hospitalized due to COPD exacerbations each week is shown in Fig. 2. The total number increased 1.5- and 1.3-fold compared to the corresponding periods in 2010 and 2009, respectively.

The number of patients increased during the period from 3 to 5 weeks after the earthquake and then decreased. We classified the patients into 3 groups in terms of the time of hospitalization after the disaster: the acute phase (first 2 weeks after the earthquake), the subacute phase (from weeks 3 to 5), and the chronic phase (from 6 weeks to 6 months). The number of patients admitted while in the subacute phase significantly increased compared to the corresponding periods in 2010 and 2009 ($p<0.05$). There were no significant differences between the patients in the acute plus subacute phase group as compared to those in the chronic phase group in terms of age, FEV1, percentage of predicted FEV1, regular medication, or long-term oxygen therapy. However, the deterioration in ADL upon admission was significantly different between the groups. The ADLs of patients were significantly decreased compared to that before the earthquake in the acute phase and subacute phase group ($p<0.01$) (Fig. 3a). In contrast, no reduction in ADL was observed during the chronic phase (Fig. 3b).

All patients with exacerbations were treated in accordance with the consensus guidelines [3]. Mechanical ventilation was required in 7 patients with NPPV and 1 patient with invasive mechanical ventilation. The in-hospital and 90-day mortalities of patients with exacerbations of COPD were 5.9% (4/68) and 13.6% (8/59), respectively. At 90 days, 9 patients had been lost to follow-up .

### 3.3. *Other pulmonary complications*

Eight patients with pneumothorax were identified during the study. None of these cases were associated with chest

**Table 3 – The characteristics and clinical courses of patients with exacerbated COPD symptoms.**

| | All ($n$=68) | Acute and subacute phases ($n$=36) | Chronic phase ($n$=32) |
|---|---|---|---|
| Age (years) | 77.5 (8.8) | 77.0 (12.3) | 78.0 (7.0) |
| Sex, male/female | 61/7 | 31/5 | 30/2 |
| *Residence* | | | |
| Home | 52 | 25 | 27 |
| Community evacuation center | 12 | 9 | 2 |
| Nursing home | 3 | 0 | 3 |
| Other hospital | 1 | 1 | 0 |
| Smoking history, pack-year | 50 (39) | 52.5 (39) | 41.9 (40) |
| *Pulmonary function test*[a] | | | |
| FEV1, L | 0.96 (0.67) | 0.96 (0.42) | 0.99 (0.92) |
| %FEV1 (%) | 49.0 (28.5) | 47.4 (26.6) | 50.4 (30.1) |
| FEV1/FVC | 0.44 (0.22) | 0.42 (0.17) | 0.49 (0.23) |
| *GOLD stage*[a] | | | |
| Stage I/II/III/IV | 6/24/18/13 | 2/13/10/8 | 4/11/8/5 |
| *Comorbidities* | | | |
| Congestive heart failure | 14 | 8 | 7 |
| Ischemic heart disease | 4 | 4 | 0 |
| Chronic liver disease | 2 | 1 | 1 |
| Chronic renal disease | 1 | 1 | 0 |
| Diabetes | 6 | 3 | 3 |
| Cancer | 11 | 6 | 5 |
| *Regular treatment* | | | |
| Anticholinergic | 46 | 24 | 22 |
| Long-acting beta agonist | 44 | 26 | 18 |
| Inhaled corticosteroid | 23 | 15 | 8 |
| Theophylline | 16 | 13 | 3 |
| Macrolide | 5 | 5 | 0 |
| Oral prednisolone | 5 | 4 | 1 |
| Long-term oxygen therapy | 15 | 7 | 8 |
| Chest infiltrate | 36 | 18 | 18 |
| Length of stay (days) | 11 (11.5) | 9 (11.3) | 13 (14) |
| *Prognosis* | | | |
| In-hospital death | 4 | 1 | 3 |
| Death within 90-days[b] | 8 | 4 | 4 |

Each data-point is presented as a number or median (interquartile range).
FEV1: forced expiratory volume in 1 s, %FEV1: percentage of predicted FEV1.
[a] Pulmonary function testing was not available in 7 patients.
[b] At 90 days, 9 patients had been lost to follow-up.

trauma. Six patients were treated conservatively, and 2 patients underwent thoracoscopic surgeries. Seven patients were cured, but 1 patient with very severe COPD required invasive mechanical ventilation and died due to complicating pneumonia. Six and 7 patients with pneumothorax were identified in the years 2009 and 2010, respectively. No patient included in the study experienced a pulmonary embolism.

## 4. Discussion

The findings of our study indicate that the Great East Japan Earthquake had a strong negative impact on clinical outcomes among COPD patients. In the acute phase of the disaster, patients with very severe COPD sought refuge in our hospital and were provided with oxygen therapy. A population 3 times as big was admitted due to exacerbated symptoms. During the chronic phase, the frequency of admission due to exacerbations returned to baseline levels.

During the acute phase, most of the COPD patients who presented at the hospital were seeking oxygen therapy. In Japan, home oxygen therapy is widely used for patients with chronic respiratory failure and is covered by the national healthcare insurance system [6]. Since the Hanshin–Awaji earthquake in 1995, medical personnel and oxygen-service providers have recognized the importance of managing oxygen-dependent patients during a disaster and have established emergency operation measures. The wide-scale disaster of 2011, however, was more catastrophic than predicted in even the most pessimistic scenarios. Fortunately, we were able to accept many oxygen-dependent patients who were normally treated at other clinics in addition to our own outpatients.

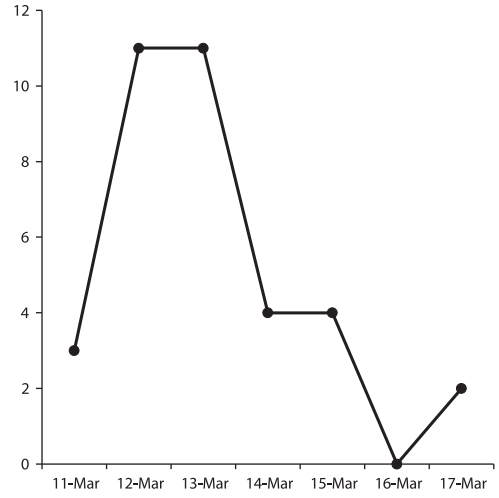


**Fig. 1 – Number of oxygen-dependent patients who visited the hospital after the earthquake.**

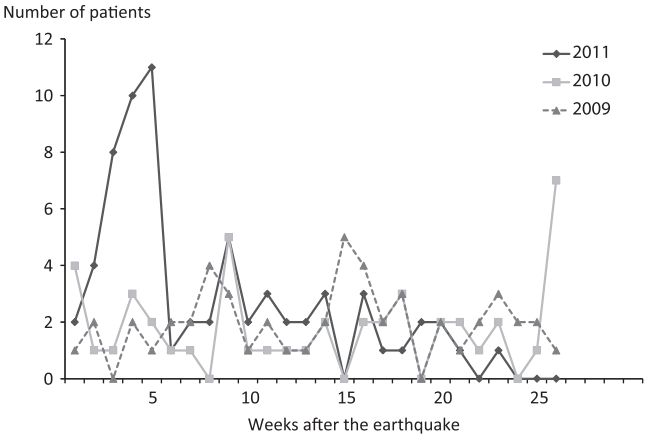


**Fig. 2 – Numbers of patients hospitalized due to COPD exacerbations per week for 6 months after the disaster, and during the corresponding periods in 2010 and 2009.**

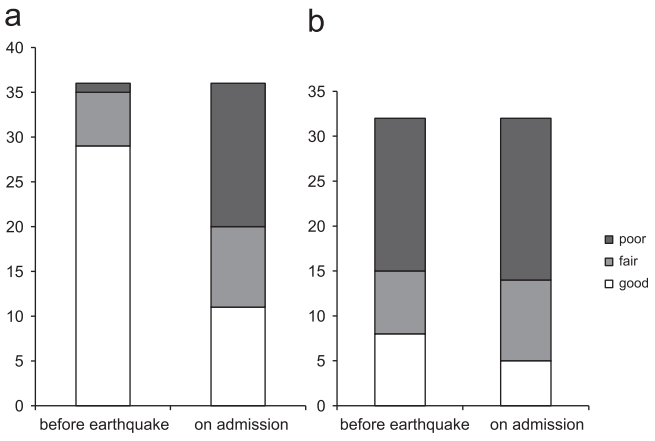


**Fig. 3 – Comparison of patient ADL values prior to the earthquake, upon admission in the acute plus subacute phases group (a) and in the chronic phase group (b). ADL was classified as good, fair, or poor (see the text for more detail).**

The evacuees were not hospitalized because all of the hospital beds were occupied by casualties who were seriously ill. Instead, each COPD patient was provided with a continuous oxygen supply via the central gas piping system in the outpatient ward. The unexpectedly high number of patients exceeded the facility's capacity for sound care. Therefore, on March 14, we established a temporary oxygen therapy center inside the hospital using electric oxygen concentrators. This area had been used as a rehabilitation center before the disaster and lacked an oxygen piping system [5]. Trained nurses in the Respiratory Medicine Department were assigned to the evacuation center to provide medical care, and respiratory physicians visited each outpatient every day. Nevertheless, there was a high incidence of symptom exacerbation among those patients staying at the evacuation center. Symptom severity was likely exacerbated by the facility's poor insulation [7,8] and the interruption of regular treatment [9]. Some patients had been drenched by the tsunami, while others, prior to their hospital visit, stayed in houses or shelters that not only lacked oxygen supplies but also lacked heating systems or water supplies. Some patients were also deprived of their prescribed drugs, and this interruption of regular treatment may have partly contributed to the worsening of symptoms.

The symptoms of many patients worsened during the subacute phase. The number of patients hospitalized due to exacerbated symptoms was 3 times higher than those hospitalized during the corresponding period in 2009 or 2010. First, interruption of regular treatment may have resulted in increase in exacerbations of COPD [9]. In addition to the factors cited above, tracheobronchial infections may be associated with worsened COPD symptoms. Previous reports demonstrated that respiratory infections increased in the aftermath of a massive earthquake [10,11]. In Ishinomaki and the surrounding areas, habitants suffered insufficient fuel supplies, power failures, water and food shortages, and an inability to maintain the appropriate level of personal hygiene. These conditions were compounded by cold winter temperatures and damaged houses or emergency shelters [2]. Such unfavorable conditions are likely to result in the increased occurrence of respiratory infections. The inhalation of dust and fine particles from rubble and tsunami-sludge also make breathing difficult. It has been reported that air pollution is an important risk factor for the exacerbation of COPD [12,13]. Many buildings in Ishinomaki were destroyed by the tsunami, and the entire area was covered by a thick layer of mud. Thus, chemicals, particulates, and biological materials from debris and tsunami-sludge may have contributed to the worsening of respiratory symptoms among COPD patients in the area hit by the tsunami.

The deterioration of ADLs in the acute and subacute phases after the disaster resulted in increased number of hospitalizations (Fig. 3a). It was previously reported that physical disability was an independent risk factor for death after the Hanshin–Awaji earthquake [14] and the 1999 Taiwan earthquake [15]. However, those reports investigated mortality in the acute phase, but not hospitalizations in the subacute or chronic phases. Recent reports have also demonstrated that physical inactivity is a risk factor for symptom aggravation and mortality in COPD [16,17]. After the earthquake and

tsunami in the Ishinomaki region, over 40,000 evacuees stayed at crowded emergency shelters, where they had to lie down on the floor without beds. Elderly patients with COPD were largely sedentary, which led to ADL deterioration. Furthermore, impaired ADLs and poor oral hygiene induced swallowing dysfunction, which can in turn exacerbate COPD [18].

The number of patients presenting with COPD exacerbations declined in the chronic phase as compared to the subacute phase. The recovery of water and food supplies, the restoration of vital infrastructure and medical services, and the improvement in living conditions may have contributed to this phenomenon. In Ishinomaki and the surrounding cities, medical relief teams circulated around community evacuation centers and prescribed medications for patients with chronic disease [2]. These efforts minimized the interruption of treatment during the chronic phase.

Diagnoses of pneumothorax [19] and pulmonary embolism [20] should be considered in COPD patients reporting exacerbated symptoms, even in the aftermath of natural disasters. In this study, we identified 8 patients with pneumothorax, and none with pulmonary embolism. Patients whose symptoms had worsened underwent comprehensive evaluation, including chest radiography, which led to the detection of pneumothorax in several patients.

The major limitation of our study is its single-center, retrospective design. The Japanese Red Cross Ishinomaki Hospital is the only regional respiratory center in the Ishinomaki medical-care zone. In 2009, we established a regional medical liaison system to provide patients with comprehensive care in Ishinomaki and the surrounding region. This collaboration involved general practitioners, pharmacies, rehabilitation clinics, and home-visit nursing stations. The system was set up so that our hospital accepted all COPD patients with respiratory emergencies who were located in the Ishinomaki medical care-zone and required hospital management. Therefore, the results of our study will accurately reflect the impact of the disaster on COPD symptoms.

Another limitation of this study was that some data were not available due to disruptions caused by the disaster. We had to exclude some patients who had chronic respiratory symptoms and emphysema as diagnosed by chest radiography, but did not confirm the diagnosis with a pulmonary function test. Although we tried to contact the hospital to ascertain patient outcomes, some patients that were referred to rearward hospitals could not be followed up.

To our knowledge, this is the first retrospective study to determine outcomes in patients with COPD who experienced a large-scale natural disaster in a developed nation with an aging population. Although pulmonary complications, such as chest trauma or respiratory infection, are commonly recognized after natural disasters [21,22], the impact on the outcomes of COPD patients had not previously been clarified [23]. The results of our study indicate that patients with COPD will suffer substantially in the aftermath of natural disasters.

In conclusion, the present study demonstrates that large-scale natural disasters have a negative impact on clinical outcomes among COPD patients in the affected area. Further studies are required to determine how various types of natural disasters influence clinical outcomes. Our results suggest that respiratory physicians, in cooperation with disaster specialists, should develop strategies for the management of COPD patients in the aftermath of natural disasters.

## Conflict of interest

The authors have no potential conflict of interest.

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